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GaN Defects Observed by EBIC, AFM, and CL

NASA NEPP – June 2014

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Background

Current – Post characterization by CL or AFM or TEM…

New – Pre and Post characterization linked metrology

- EBIC, SEM , AFM and CL

- determine previously existed, formed, diffused, increased, or diminish

- Focused points of interest

- Directly measure the impact

- Lifetime

- Performance

Evolution of structural defects associated with electrical degradation in AlGaN/GaN high electron mobility transistors

Prashanth Makaram, Jungwoo Joh, Jesús A. del Alamo, Tomás Palacios, and Carl V. Thompson

Appl. Phys. Lett. 96, 233509 (2010)

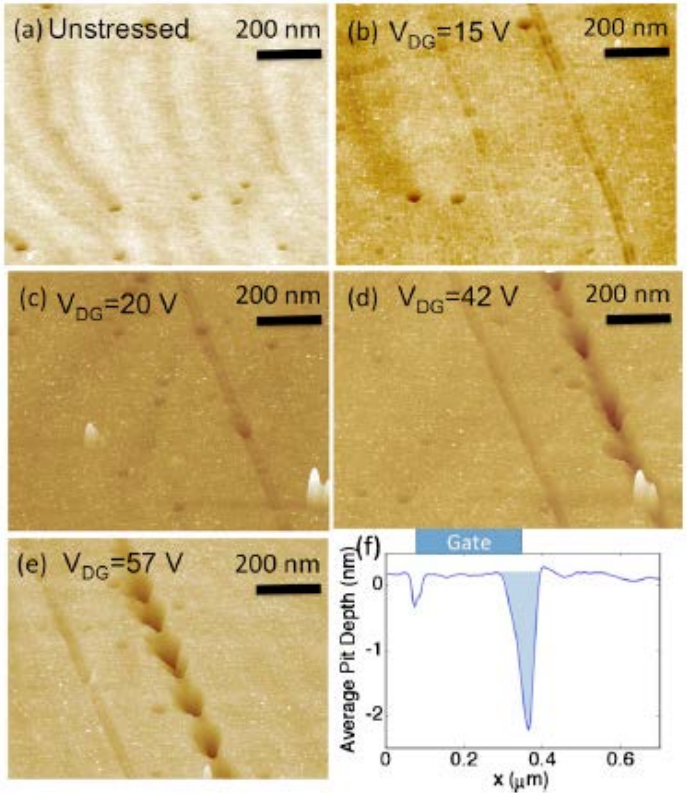
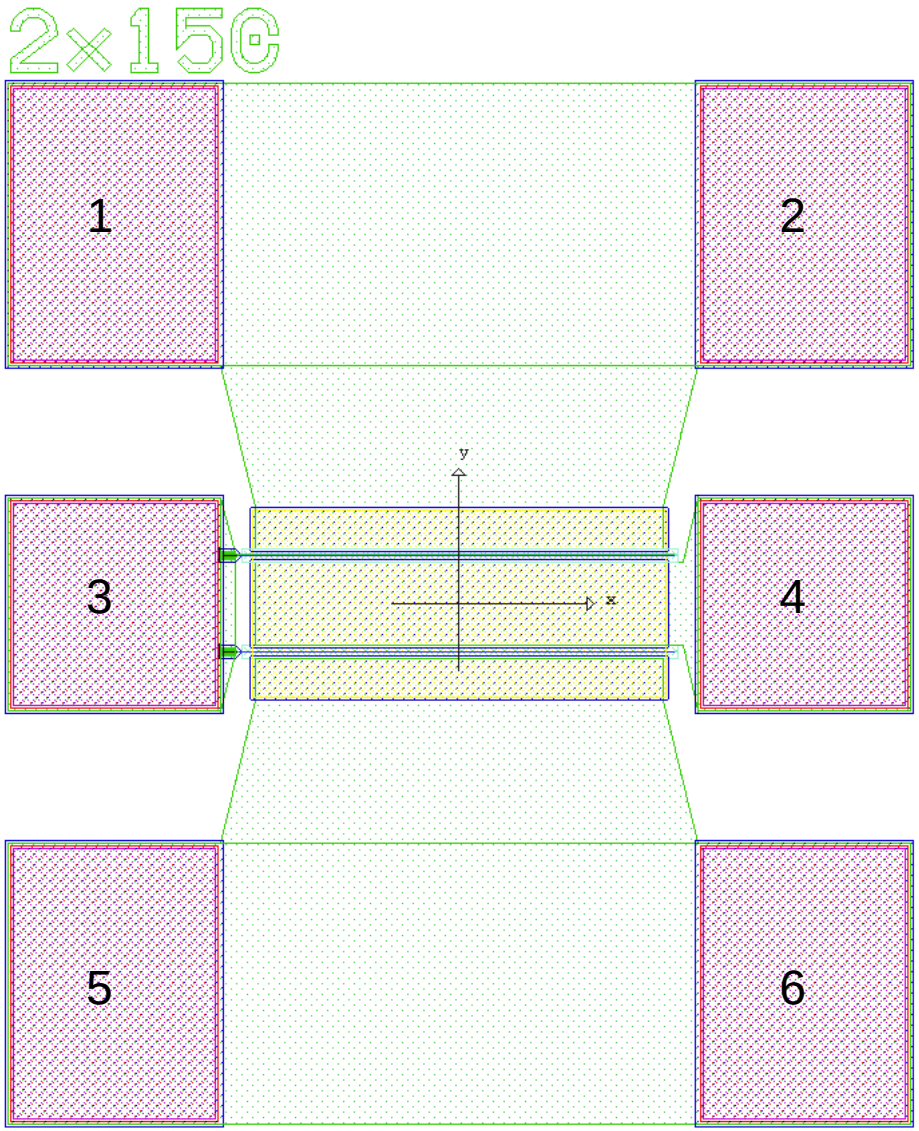


FIG. 3. (Color online) Progressive structural damage with voltage stress (a) unstressed device, (b) $V_{DGstress}$=15 V<V_{crit}, (c)$V_{DGstress}$=20 V≅V_{crit}, (d) $V_{DGstress}$=42 V, and (e) $V_{DGstess}$=57 V. (f) Averaged AFM depth profile over a gate width of 2 μm for the most degraded device ($V_{DGstress}$ =57 V).

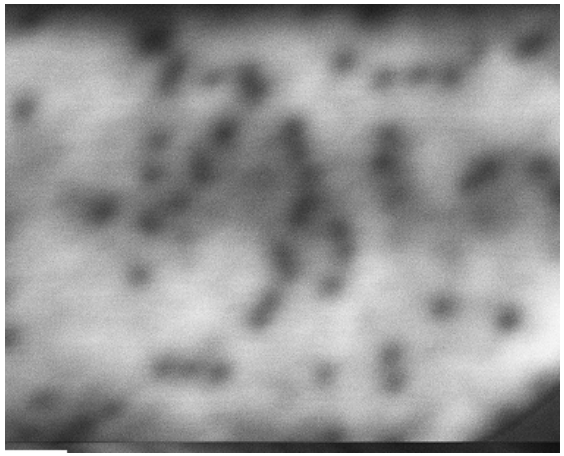
Formation of pits at the drain side of the gate after electrical stress has been reported.

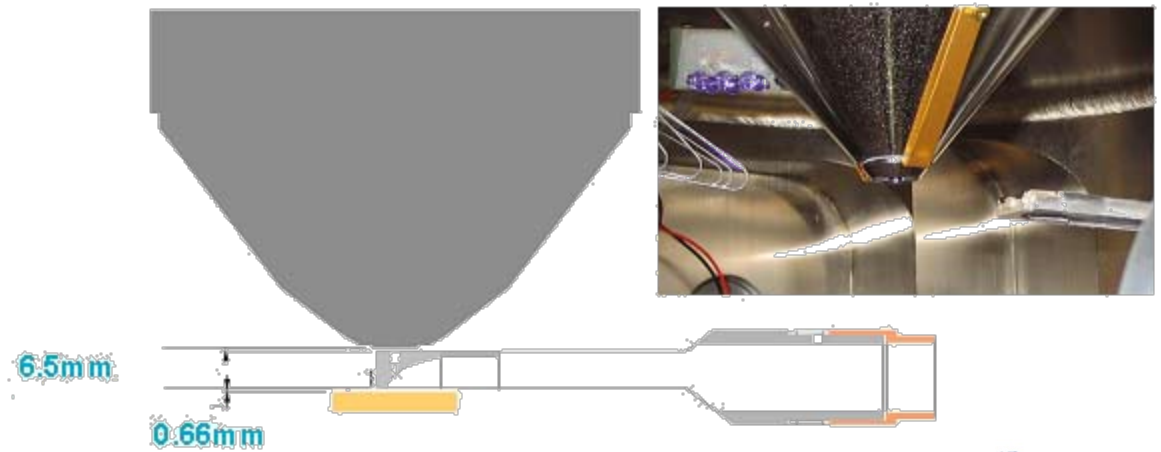
AFRL Devices used in Study



Cathodoluminescence

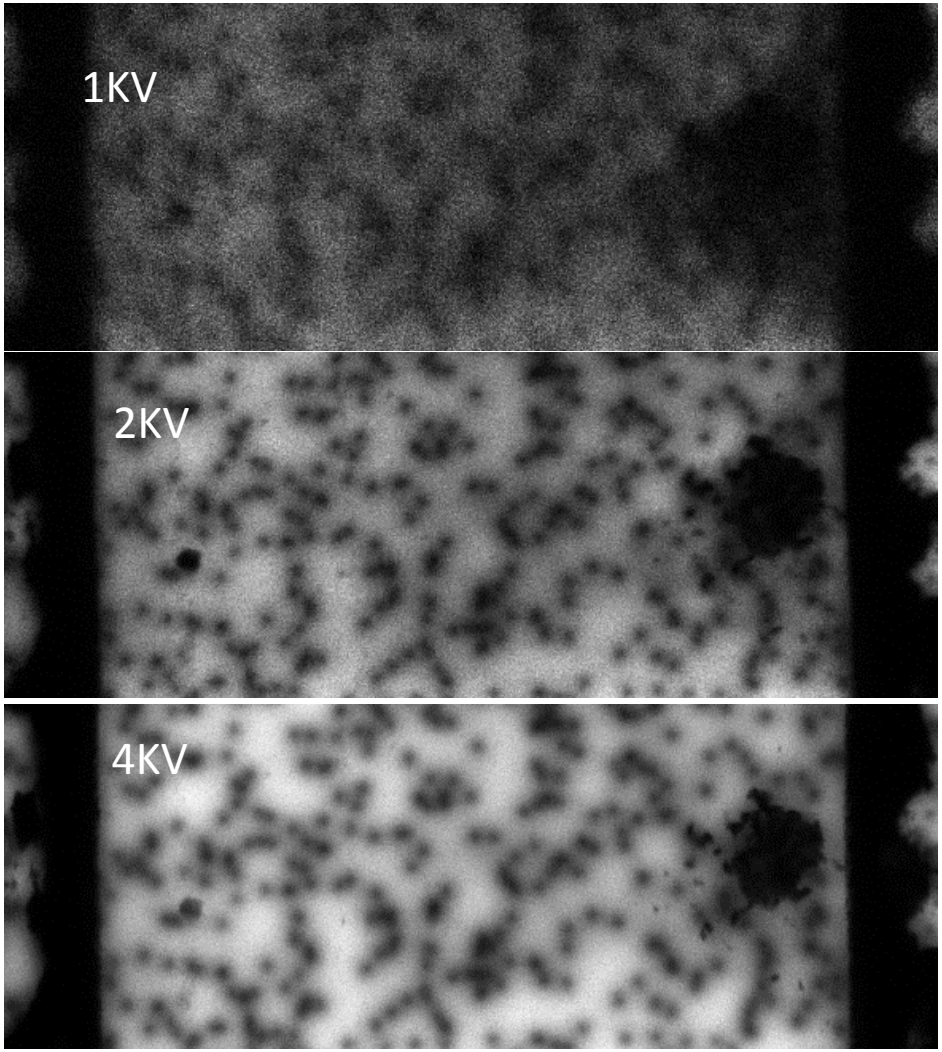
- **Cathodoluminescence is the optical and electromagnetic phenomenon that is produced when electrons from a electron gun, interact with the material.**



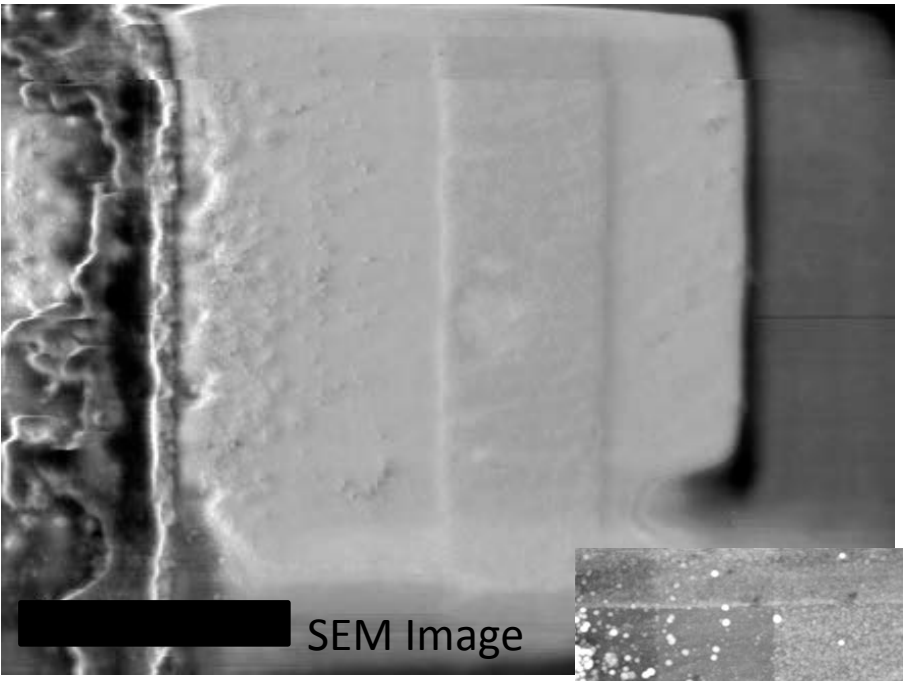


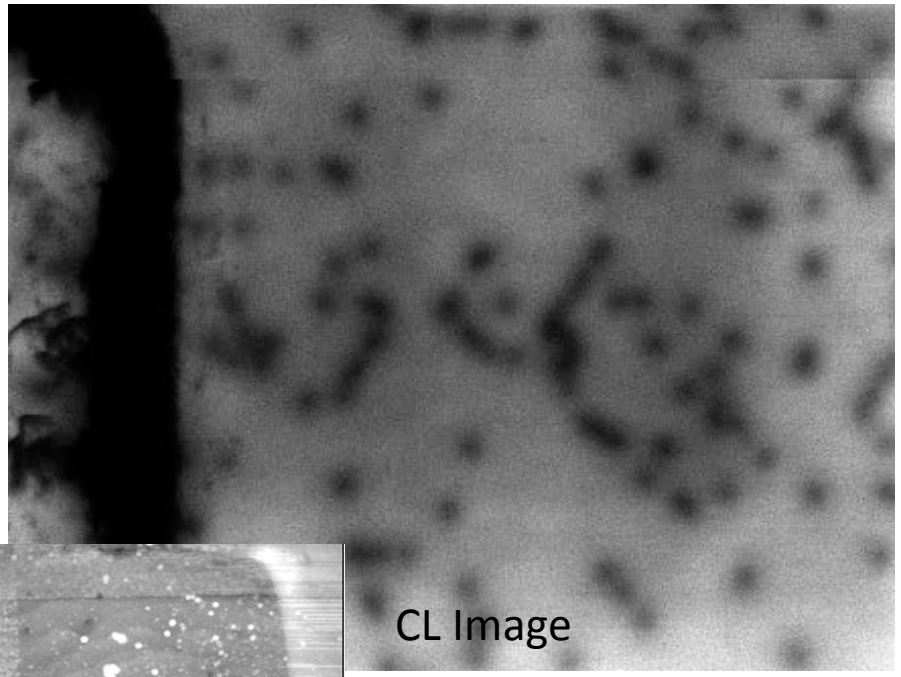
Optimize CL and Depth Resolution

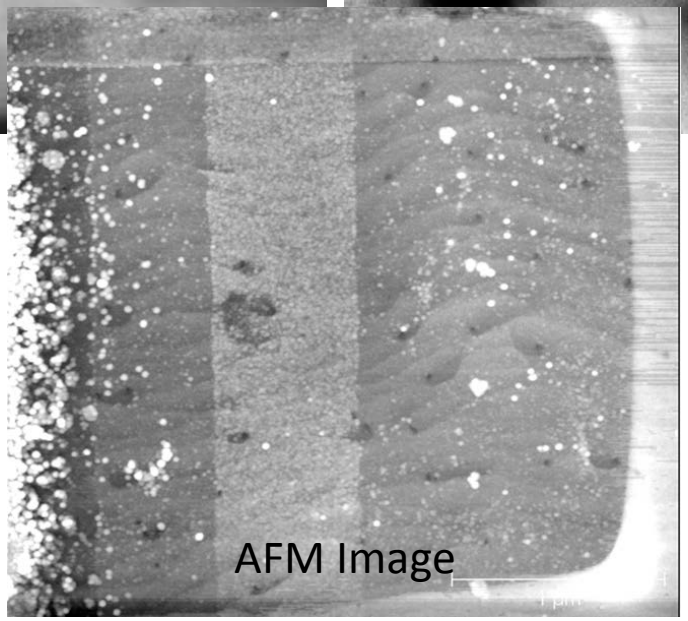
- Optimized spatial resolution
- Minimized depth and lateral interference.
- Distinguish any surface artifact.



Images

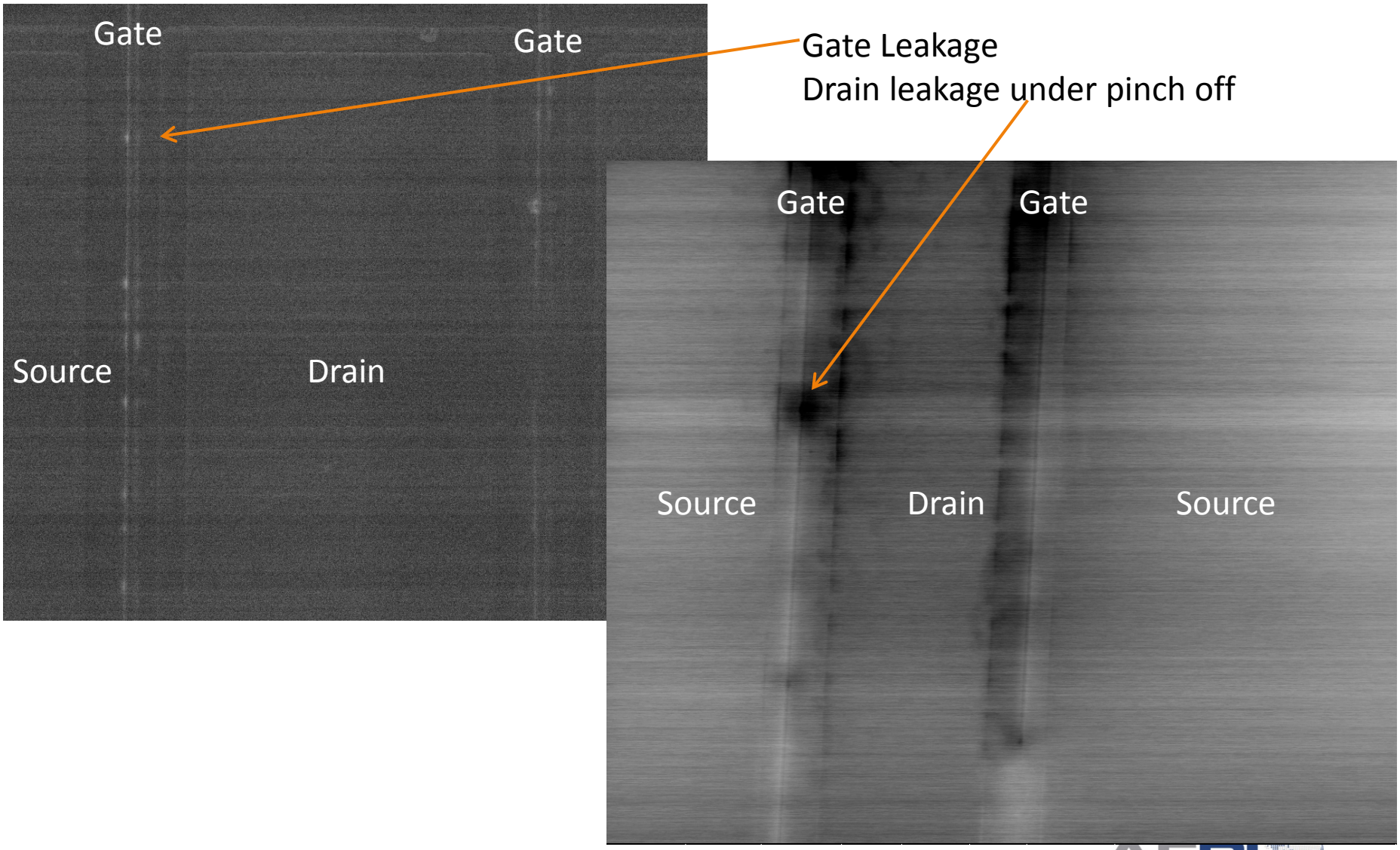




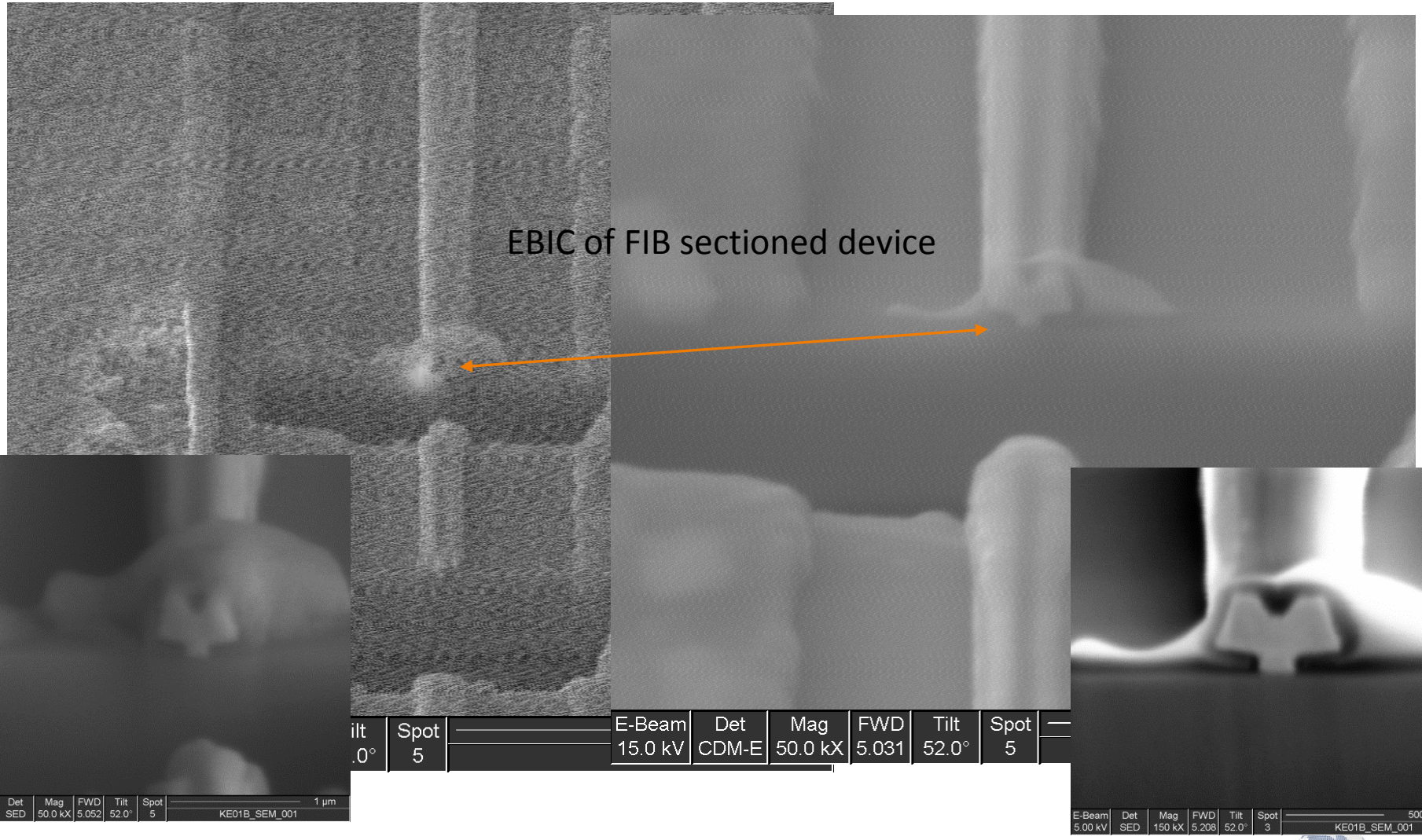


AFM completed by Al Hilton – Wyle Labs

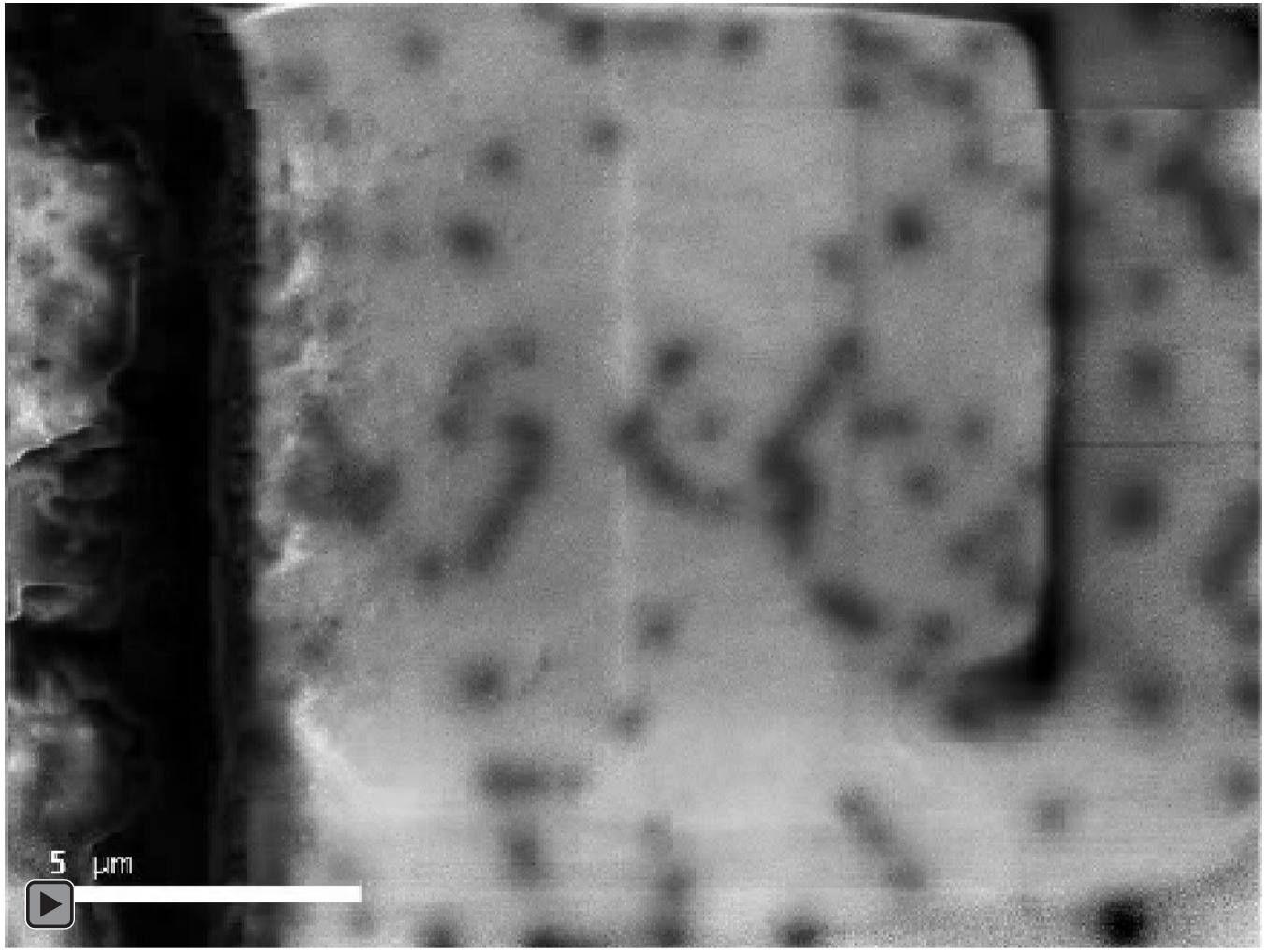
EBIC of GaN Device Parameters



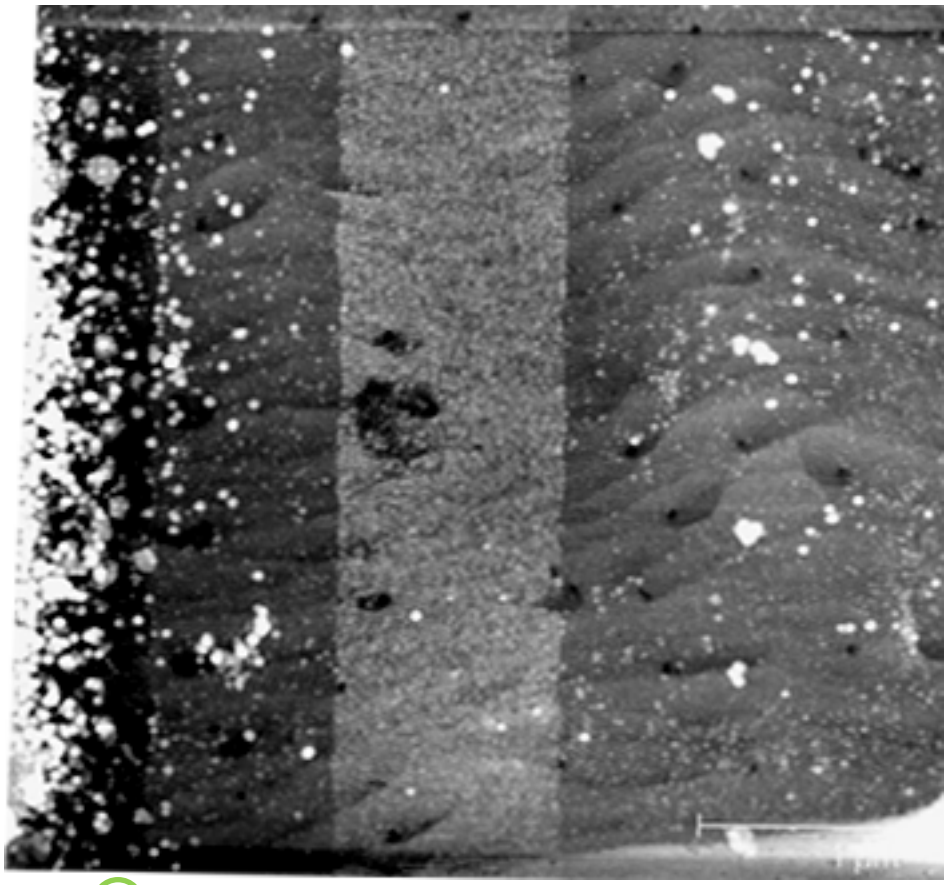
EBIC Cross Section Site 1

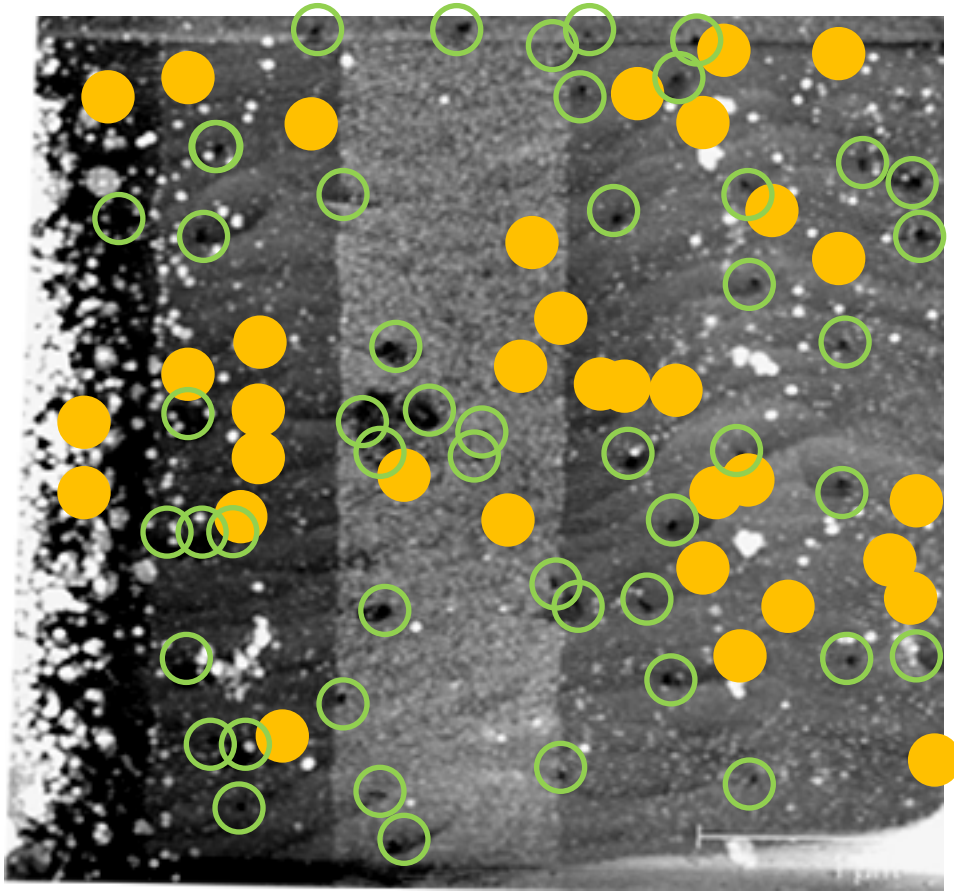


Video of 1:1 process of Map correlation SEM to CL to AFM



CL correlation to AFM points





- 48 - CL points that have a corresponding AFM pit
- 34 - CL points that do not have a corresponding AFM pit

All AFM pits mapped to CL points

Summary

- New tools and techniques developed that locate points of interest and optimized test methods for use during fabrication and pre/post stress.
- Build beyond current methodology to close the loop – parametric changes, evolving behavior and materials characterization
- Developed effective registration capability to overlay different images

Future Work

- Use tools to measure changes and test hypothesis within the device during fabrication and pre/post stress.
- Integrate methodology into our FA tool set for pre/post stress analysis
  - Determine true distribution of defects
  - Analyze intrinsic vs. stress induced
  - Quantify cost/merit of various FA tools
- Directly correlate GaN defects to surface and electrical parametric characteristics.

Simultaneous SEM CL and EBIC